UNIVERSITY OF NEBRASKA - LINCOLN
(Center Pivot Spray Irrigation System)

TECHNOLOGY DESCRIPTION:

Spray irrigation technology with "Center Pivots" and "Linear" systems can be used to remediate groundwater contaminated with volatile organic compounds (VOC). The technology is commonly used to apply irrigation water to vegetable and row crops. While the systems were introduced to irrigate hilly terrain and excessively well-drained soils, the technology has been adapted in both groundwater quality and quantity management areas as a best management practice. This technology severely reduces water application rates and leaching relative to flood irrigation techniques.

The systems consist of an elevated pipeline with nozzles placed at close intervals. Groundwater is pumped through the pipeline and sprayed uniformly over a field as the pipeline pivots or linearly passes over the cropped area. The typical pump rate is between 800 and 2,000 gallons per minute (gpm). These self-propelled systems are highly mechanized and have low labor andoperating requirements. The systems do not require level ground and startup costs are low.

The sprinkler method applies water over the irrigated area with a fine spray (see the photograph below). Water coverage over the irrigated area is controlled by the speed with which the "pivot" or "linear" systems travel across the field. The heart of the sprinkler irrigation system is the nozzle, which is a small opening through which a high-velocity stream of water is emitted. As the high-velocity water stream leaves the nozzle, it strikes an impact pad and forms a thin film of water.

The system used in the SITE demonstration program was a center pivot and was located on a seed corn field in Hastings, Nebraska. The system was equipped with off-the-shelf, fog-producing impact pads for improved volatilization efficiency. The thin film of water produced by these pads breaks up into small droplets as it leaves the impact pad. Droplet size depends on the stream pressure and design of the impact pad.

A stratified water droplet collector (SWDC) simultaneously

Center Pivot Spray Irrigation System

collected spray at four fall heights above ground level, and was specifically contracted for this project by the Dutton-Lainson Company in Hastings, Nebraska. With this device, droplets were collected at heights of 1.5, 4.5, 7.5, and 10.5 feet above the ground surface. Twelve SWDCs were installed parallel to the pivot arm to determine average volatilization efficiencies along the 340 nozzles on the pivot arm.

WASTE APPLICABILITY:

The sprinkler irrigation system is capable of remediating VOC-contaminated groundwater. Removal rates in excess of 95 percent have been demonstrated for groundwater containing ethylene dibromide (EDB), trichloroethene (TCE), 1,1,1-trichloroethane (TCA), and carbon tetrachloride (CT). The method will efficiently volatilize all common volatiles in groundwater which may originate from landfills, degreasers, dry cleaners, electrical industries, gas stations, or refineries. The residuals are transferred to the atmosphere, where they are dispersed and most are rapidly degraded in ultraviolet light.

The technique may be limited to individual groundwater VOC concentrations that are less than 1 part per million if residual concentrations of VOCs are mandated to be near or below the maximum contaminant level prior to reaching the ground surface. Otherwise, the technique can be used in any agricultural setting where sufficient groundwater and irrigatable land are available.

STATUS:

The Center Pivot Spray Irrigation system was accepted into the SITE Program in late 1995. Under a University of Nebraska project funded by the Cooperative State Research Service of the Department of Agriculture, field tests were completed in the summers of 1994 and 1995 in a seed corn field in Hastings, Nebraska.

The technology was demonstrated under the SITE Program in July 1996 at the North Landfill Subsite in Hastings, Nebraska. The 50-acre site is a furrow-irrigated corn field underlain by commingled plumes of groundwater containing EDB, TCE, TCA, CT, 1,1-dichloroethene, trans-1,2-dichloroethene, and chloroform. The primary goal of the demonstration was to determine the efficiency of the system to remediate VOCs in groundwater to concentrations below the maximum contaminant levels. The results of this demonstration will be available in a Demonstration Bulletin and Innovative Technology Evaluation Report to be published early in 1997.

Clients involved in large pump-and-treat projects at several military bases are investigating the suitability of the system to their specific site situations. Potential clients include the U.S. Navy, the Army Corp of Engineers, and several state agencies. The technology is currently being used at the Lindsey Manufacturing site in Nebraska and at some grain elevators being remediated by Argonne Laboratory.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Teri Richardson
EPA SITE Project Manager
U.S. EPA
National Risk Management Research Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7949
Fax: 513-569-7105

TECHNOLOGY DEVELOPER CONTACT:
Roy Spalding
University of Nebraska - Lincoln
Water Center/Environmental Programs
103 Natural Resources Hall
P.O. Box 830844
Lincoln, NE 68583-0844
402-472-7558
Fax: 402-472-9599

WASTECH, INC.
(Solidification and Stabilization)

TECHNOLOGY DESCRIPTION:

This technology solidifies and stabilizes organic and inorganic contaminants in soils, sludge, and liquid wastes. First, a proprietary reagent chemically bonds with contaminants in wastes. The waste and reagent mixture is then mixed with pozzolanic, cementitious materials, which combine to form a stabilized matrix. Reagents are selected based on target waste characteristics. Treated material is a nonleaching, high-strength, stabilized end-product.

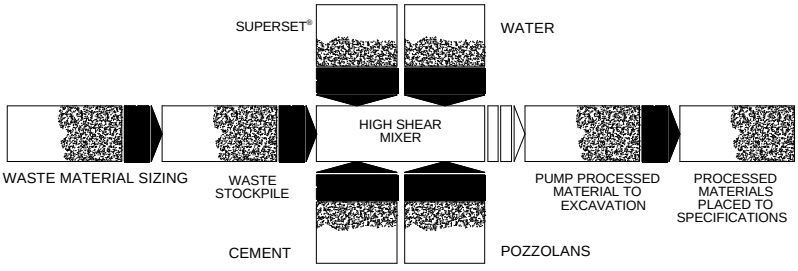
The WASTECH, Inc. (WASTECH), technology uses standard engineering and construction equipment. Because the type and dose of reagents depend on waste characteristics, treatability studies and site investigations must be conducted to determine the proper treatment formula.

Treatment usually begins with waste excavation. Large pieces of debris in the waste must be screened and removed. The waste is then placed into a high shear mixer, along with premeasured quantities of water and SuperSet®, WASTECH's proprietary reagent (see figure below).

Next, pozzolanic, cementitious materials are added to the waste-reagent mixture, stabilizing the waste and completing the treatment process. The WASTECH technology does not generate by-products. The process may also be applied in situ.

WASTE APPLICABILITY:

The WASTECH technology can treat a wide variety of waste streams consisting of soils, sludges, and raw organic streams, including lubricating oil, evaporator bottoms, chelating agents, and ion-exchange resins, with contaminant concentrations ranging from parts per million levels to 40 percent by volume. The technology can also treat wastes generated by the petroleum, chemical, pesticide, and wood-preserving industries, as well as wastes generated by many other chemical manufacturing and industrial processes. The WASTECH technology can also be applied to mixed wastes containing organic, inorganic, and radioactive contaminants.



WASTECH Solidification and Stabilization Process

STATUS:

The technology was accepted into the SITE Demonstration Program in spring 1989. A field demonstration at Robins Air Force Base in Warner Robins, Georgia was completed in August 1991. WASTECH subsequently conducted a bench-scale study in 1992 under glovebox conditions to develop a detailed mass balance of volatile organic compounds. The Innovative Technology Evaluation Report will be available in 1997. The technology is being commercially applied to treat hazardous wastes contaminated with various organics, inorganics, and mixed wastes.

This technology is no longer available from the vendor. For further information about the process, contact the EPA Project Manager.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Terrence Lyons
U.S. EPA
National Risk Management Research Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7589
Fax: 513-569-7676

ROY F. WESTON, INC.
(Low Temperature Thermal Treatment System)

TECHNOLOGY DESCRIPTION:

The Roy F. Weston, Inc. (Weston), low temperature thermal treatment (LT³®) system thermally desorbs organic compounds from contaminated soil without heating the soil to combustion temperatures. The transportable system (see photograph below) is assembled on three flat-bed trailers and requires an area of about 5,000 square feet, including ancillary and support equipment. The LT³® system consists of three segments: soil treatment, emissions control, and water treatment.

The LT³® thermal processor consists of two jacketed troughs, one above the other. Each trough houses four intermeshed, hollow screw conveyors. A front-end loader feeds soil or sludge onto a conveyor that discharges into a surge hopper above the thermal processor. Hot oil circulating through the troughs and screws heats the soil to 400 to 500 °F, removing contaminants. A second stage indirect heater is available to achieve 1,000 °F discharge temperatures. Soil is discharged from the thermal processor into a conditioner, where a water spray cools the soil and minimizes dust emissions.

A fan draws desorbed organics from the thermal processor through a fabric filter baghouse. Depending on contaminant characteristics, dust collected on the fabric filter may be retreated, combined with treated material, or drummed separately for off-site disposal. Exhaust gas from the fabric filter is drawn into an air-cooled condenser to remove most of the water vapor and organics. The gas is then passed through a second, refrigerated condenser and treated by carbon adsorption.

Condensate streams are typically treated in a three-phase, oil-water separator to remove light and heavy organic phases from the water phase. The water phase is then treated in a carbon adsorption system to remove residual organic contaminants. Treated condensate is often used for soil conditioning, and

Low Temperature Thermal Treatment (LT³®) System

only the organic phases are disposed of off site.

WASTE APPLICABILITY:

This system treats soils and sludges contaminated with volatile and semivolatile organic compounds (VOC and SVOC). Bench-, pilot-, and full-scale LT³® systems have treated soil contaminated with the following wastes: coal tar, drill cuttings (oil-based mud), No. 2 diesel fuel, JP-4 jet fuel, leaded and unleaded gasoline, petroleum hydrocarbons, halogenated and nonhalogenated solvents, VOCs, SVOCs, polynuclear aromatic hydrocarbons, polychlorinated biphenyls, pesticides, herbicides, dioxins, and furans.

STATUS:

The LT³® system was accepted into the SITE Demonstration Program in September 1991. In November and December 1991, the LT³® system was demonstrated under the SITE Program as part of a proof-of-process test for full-scale remediation of the Anderson Development Company (ADC) Superfund site in Adrian, Michigan. The system was tested on lagoon sludge from the ADC site. This sludge was contaminated with VOCs and SVOCs, including 4,4-methylene bis(2-chloroaniline) (MBOCA).

The Demonstration Bulletin (EPA/540/MR-92/019) and Applications Analysis Report (EPA/540/AR-92/019) are available from EPA.

DEMONSTRATION RESULTS:

During the demonstration, the system throughput was approximately 2.1 tons per hour. Six replicate tests were conducted, each lasting approximately 6 hours. The SITE demonstration yielded the following results:

- The LT³® system removed VOCs to below method detection limits (less than 0.060 milligram per kilogram [mg/kg] for most compounds).
- The LT³® system achieved MBOCA removal efficiencies greater than 88 percent; MBOCA concentrations in the treated sludge ranged from 3.0 to 9.6 mg/kg.
- The LT³® system decreased the concentrations of all SVOCs in the sludge, with the exception of phenol, which increased possibly due to chlorobenzene.
- Dioxins and furans were formed in the system, but the 2,3,7,8-tetra-chlorodibenzo-p-dioxin isomer was not detected in treated sludges.
- Stack emissions of nonmethane total hydrocarbons increased from 6.7 to 11 parts per million by volume during the demonstration; the maximum emission rate was 0.2 pound per day (ppd). The maximum particulates emission rate was 0.02 ppd, and no chlorides were measured in stack gases.

The economic analysis of the LT³® system's performance compared the costs associated with treating soils containing 20, 45, and 75 percent moisture. The treatment costs per ton of material were estimated to be $37, $537, and $725, respectively.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Paul dePercin
U.S. EPA
National Risk Management Research Laboratory
26 West Martin Luther King Avenue
Cincinnati, OH 45268
513-569-7797
Fax: 513-569-7105
E-Mail: dePercin.Paul@epamail.epa.gov

TECHNOLOGY DEVELOPER CONTACT:
Mike Cosmos
Roy F. Weston, Inc.
1 Weston Way
West Chester, PA 19380-1499
610-701-7423
Fax: 610-701-5035

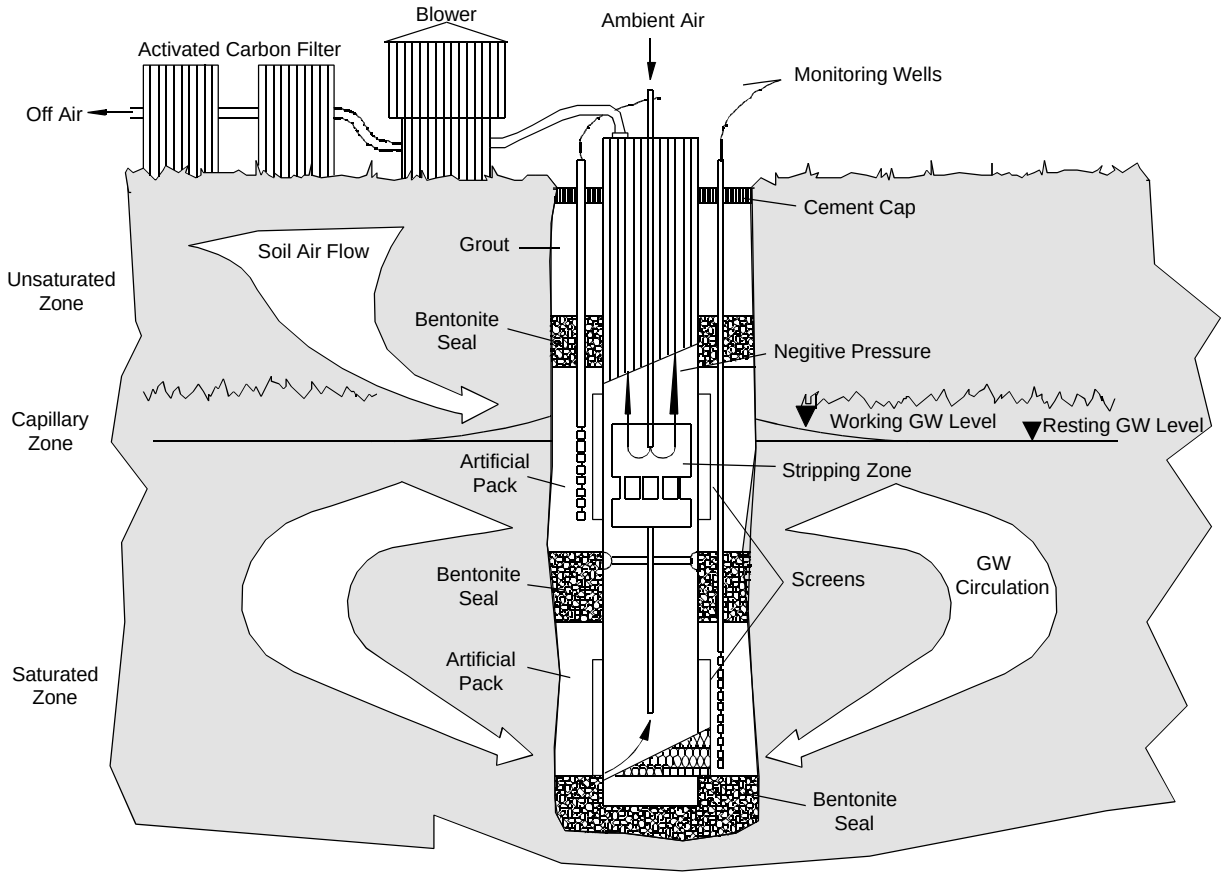
ROY F. WESTON, INC./IEG TECHNOLOGIES
(UVB - Vacuum Vaporizing Well)

TECHNOLOGY DESCRIPTION:

The Unterdruck-Verdampfer-Brunnen (UVB) vacuum vaporizing well is an in situ system for remediating contaminated aquifers, especially those contaminated with volatile organic compounds (VOC). The UVB system uses a combination of chemical, physical, and biological processes.

A UVB system consists of a specially adapted groundwater well, a negative pressure stripping reactor, an aboveground mounted blower, and a waste air decontamination system such as activated carbon beds (see figure below).
The water level rises about 1 foot inside the well due to negative pressure generated by a blower. Fresh air is drawn into the system through a pipe leading to the stripping reactor, and passes up through the raised water. The rising air bubbles enhance the suction effect at the bottom of the well, creating air-lift. A specific flow direction can be induced by adding a support pump to produce an upward or downward vertical flow within the well.

The contaminants vaporize into the air bubbles and are removed from the well by the air flow. The oscillating hydraulic pressure forces the water horizontally into the aquifer through the top screened well segment. In the surrounding aquifer, a circulation system develops; water enters at the well



UVB Standard Circulation

base and leaves through the upper screened segment, or vice versa, depending on the desired flow direction.

A flow pattern with a calculable horizontal and vertical component is produced in the aquifer to compensate for the directed water flow within the UVB well. Thus, treated groundwater circulates through the circulation cell within the aquifer before returning to the well.

The UVB technology can extract soil gas during groundwater treatment. The amount of soil gas and groundwater passing through the decontamination system can be adjusted according to the type of contamination and the well construction.

WASTE APPLICABILITY:

The UVB technology is designed to remove VOCs from groundwater. Depending on the circumstances, the UVB system may also remediate semivolatile organic compounds and heavy metals.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1993. The demonstration at March Air Force Base, California was completed in May 1994. The Demonstration Bulletin (EPA/540/MR-95/500), Technology Capsule (EPA/540/R-95/500a), and Innovative Technology Evaluation Report (EPA/540/R-95/005) are available from EPA.

DEMONSTRATION RESULTS:

Demonstration results indicate that the UVB system reduced trichloroethene (TCE) in groundwater by an average of greater than 94 percent. The average TCE concentration from the outlet of the UVB system in the treated groundwater was approximately 3 micrograms per liter (µg/L), with only one event above 5 µg/L. The inlet TCE concentration averaged 40 µg/L.

Results of a dye-tracer study conducted during the demonstration indicated that the radius of the circulation cell was at least 40 feet.

Modeling of the radius of the circulation cell by Roy F. Weston, Inc., suggests that it may extend to approximately 83 feet, which compares to a conventional pumping well radius of influence of 60 feet.

In general, TCE in the shallow and intermediate screened wells showed a concentration reduction both vertically and horizontally during the demonstration. TCE concentrations in these wells appeared to homogenize as indicated by their convergence and stabilization. Variations in TCE concentrations were noted in the deep screened wells.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Michelle Simon
U.S. EPA
National Risk Management Research Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7469
Fax: 513-569-7676

TECHNOLOGY DEVELOPER CONTACTS:
Jeff Bannon
Roy F. Weston, Inc.
14724 Ventura Boulevard, Suite 1000
Sherman Oaks, CA 91403
818-971-4900
Fax: 818-971-4901

Eric Klingel
IEG Technologies
5015D West W.T. Harris Boulevard
Charlotte, NC 28269
704-599-4818
Fax: 704-599-4815

WHEELABRATOR CLEAN AIR SYSTEMS, INC.
(formerly CHEMICAL WASTE MANAGEMENT, INC.)
(PO*WW*ER™ Technology)

TECHNOLOGY DESCRIPTION:

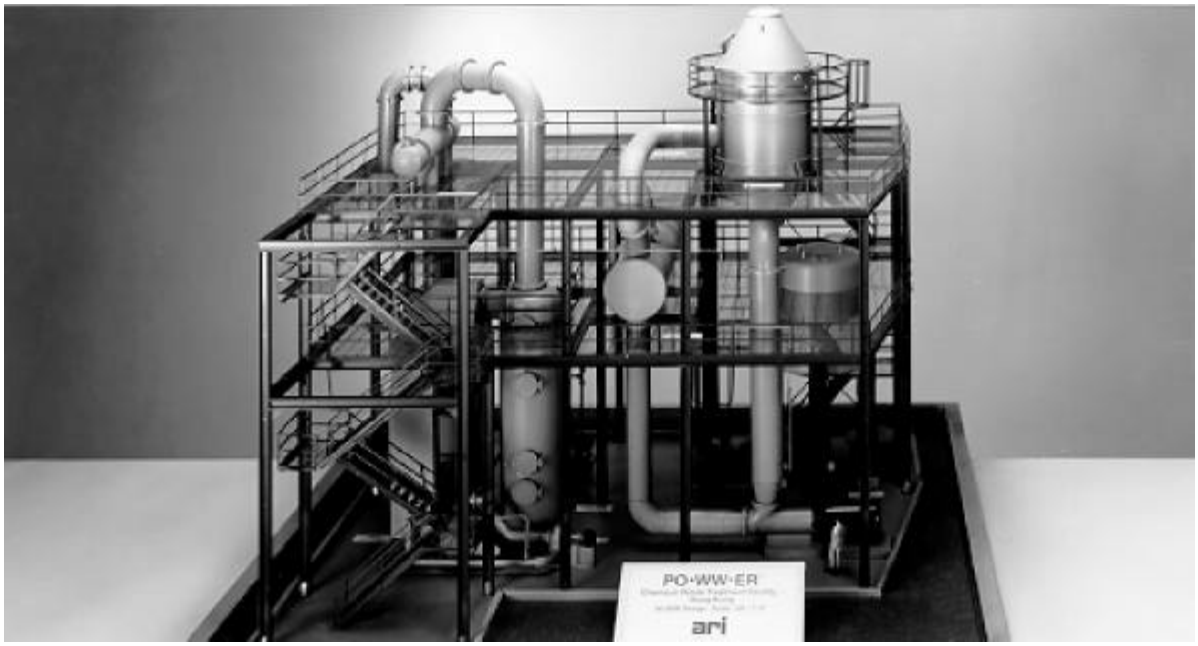
The PO*WW*ER™ technology is used to treat and reduce complex industrial and hazardous wastewaters containing mixtures of inorganic salts, metals, volatile and nonvolatile organics, volatile inorganics, and radionuclides. The proprietary technology combines evaporation with catalytic oxidation to concentrate and destroy contaminants, producing a high-quality product condensate.

Wastewater is first pumped into an evaporator, where most of the water and contaminants are vaporized and removed, concentrating the contaminants into a small volume for further treatment or disposal. The contaminant vapors then pass over a bed of proprietary robust catalyst, where the pollutants are oxidized and destroyed. Depending on the contaminant vapor composition, effluent vapors from the oxidizer may be treated in a scrubber. The vapors are then condensed to produce water (condensate) that can be used as either boiler or cooling tower makeup water, if appropriate. Hazardous wastewater can thus be separated into a small contaminant stream (brine) and a large clean water stream without using expensive reagents or increasing the volume of the total stream. The photograph below illustrates a PO*WW*ER™ - based wastewater treatment plant.

WASTE APPLICABILITY:

The PO*WW*ER™ technology can treat wastewaters containing a mixture of the following contaminants:

Organic	Inorganic	Radioactive
• Halogenated volatiles • Halogenated semivolatiles • Nonhalogenated volatiles • Nonhalogenated semi-volatiles • Organic pesticides/ herbicides • Solvents • Benzene, toluene, ethyl-benzene, and xylene • Organic cyanides • Nonvolatile organics	• Heavy metals • Nonmetallic toxic elements • Cyanides • Ammonia • Nitrates • Salts	• Plutonium • Americium • Uranium • Technetium • Thorium • Radium • Barium



PO*WW*ER™-Based Wastewater Treatment Plant

Suitable wastewaters for treatment by the PO*WW*ER™ technology include landfill leachates, contaminated groundwaters, process wastewaters, and low-level radioactive mixed wastes.

STATUS:

The technology was accepted into the SITE Demonstration Program in 1991. The demonstration took place in September 1992 at the Chemical Waste Management, Inc., Lake Charles, Louisiana facility. Landfill leachate, an F039 hazardous waste, was treated in a pilot-scale unit. The Applications Analysis Report (EPA/540/AR-93/506) and Technology Evaluation Report (EPA/540/R93/506) are available from EPA.

A commercial system with a capacity of 50 gallons per minute is in operation at Ysing Yi Island, Hong Kong. A pilot-scale unit, with a capacity of 1 to 1.5 gallons per minute, is available and can treat radioactive, hazardous, and mixed waste streams.

DEMONSTRATION RESULTS:

The ability of the PO*WW*ER™ system to concentrate aqueous wastes was evaluated by measuring the volume reduction and concentration ratio achieved. The volume of brine produced during each 9-hour test period was about 5 percent of the feed waste volume processed in the same period. The concentration ratio, defined as the ratio of total solids (TS) concentration in the brine to the TS concentration in the feed waste, was about 32 to 1.

The feed waste contained concentrations of volatile organic compounds (VOC) ranging from 320 to 110,000 micrograms per liter (μg/L); semivolatile organic compounds (SVOC) ranging from 5,300 to 24,000 μg/L; ammonia ranging from 140 to 160 milligrams per liter (mg/L); and cyanide ranging from 24 to 36 mg/L. No VOCs, SVOCs, ammonia, or cyanide were detected in the product condensate.

The PO*WW*ER™ system removed sources of feed waste toxicity. The feed waste was acutely toxic with median lethal concentrations (LC_{50}) consistently below 10 percent. The product condensate was nontoxic with LC_{50} values consistently greater than 100 percent, but only after the product condensate was cooled and its pH, dissolved oxygen level, and hardness or salinity were increased.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Randy Parker
U.S. EPA
National Risk Management Research Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7271
Fax: 513-569-7571

TECHNOLOGY DEVELOPER CONTACT:
Myron Reicher
Wheelabrator Clean Air Systems, Inc.
1501 East Woodfield Road,
Suite 200 West
Schaumberg, IL 60173
847-706-6900
Fax: 847-706-6996

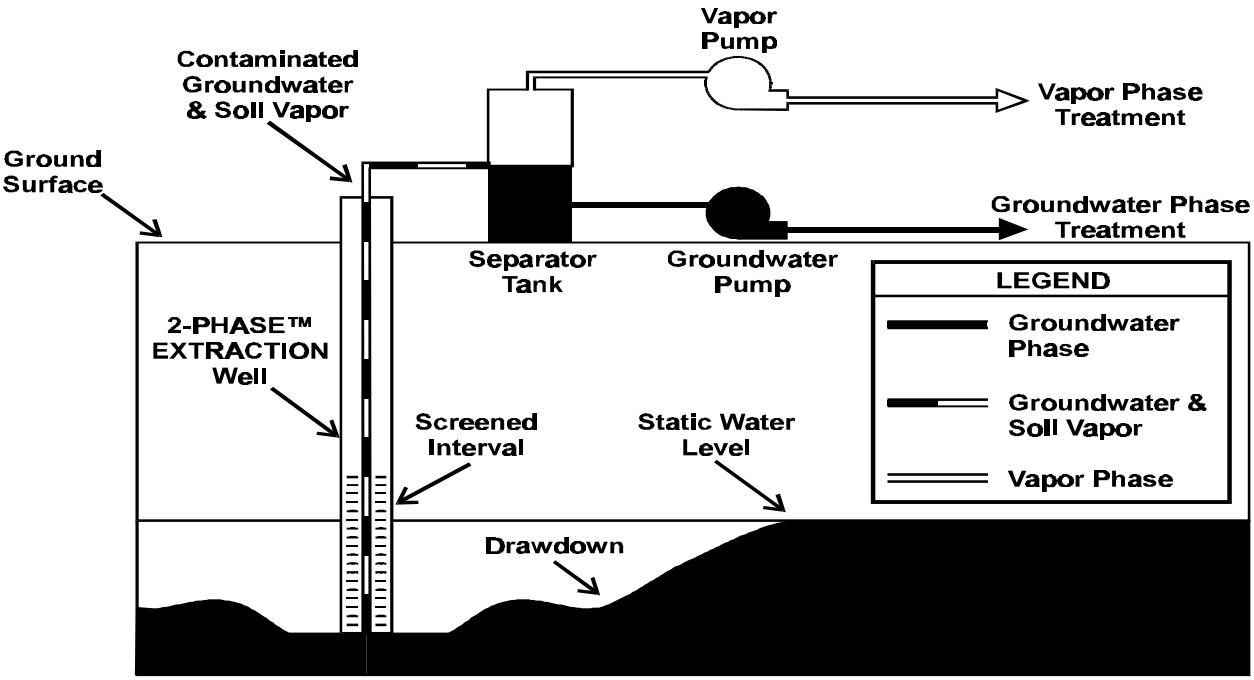
XEROX CORPORATION
(2-PHASE™ EXTRACTION Process)

TECHNOLOGY DESCRIPTION:

The 2-PHASE™ EXTRACTION Process was developed as an alternative to conventional pump-and-treat technology, particularly in low conductivity formations such as silts and clays that are impacted by volatile organic compounds (VOC). 2-PHASE™ EXTRACTION uses a high-vacuum source applied to an extraction tube within a water well to increase groundwater removal rates (consequently the dissolved phase of contamination) and to volatilize and extract that portion of contaminant from the sorbed or free product phases. Vacuum lift of water is not a limiting factor in the application of the technology. Since a mixed vapor-liquid column is extracted from the well, the 2-PHASE™ EXTRACTION technology allows a single piece of equipment (a high vacuum source) to remove contaminants in both the liquid and vapor phases.

To extract both groundwater and soil vapor from a single extraction well, the 2-PHASE™ EXTRACTION process uses a vacuum pump to apply a high vacuum (generally 18 to 29 inches of mercury) through a central extraction tube, which extends down the well. Soil vapor drawn into the well by the vacuum provides for a high velocity vapor stream at the bottom tip of the extraction tube, which entrains the contaminated groundwater and lifts it to ground surface. As groundwater moves through the extraction system, as much as 95 percent of the VOCs in the water phase are transferred to the vapor phase. The vapor and water phases are then separated at the surface in a separator tank. The water phase requires only carbon polishing prior to discharge, provided that the compounds are adsorbable. With some compounds the water carbon treatment can be eliminated. The vapor phase is subjected to carbon treatment, bioremediation, resin regeneration, catalytic oxidation, or other vapor phase treatment (based on contaminant characteristics, mass loadings, and economics) prior to release to atmosphere.

A kick-start system can induce flow and help dewater the well. The flow of atmospheric air can be regulated by adjustment of the gate valve to: (1) optimize the air-to-water flow ratio to minimize



Schematic of the 2-PHASE™ EXTRACTION Process

water "slug" production at startup (the term slug refers to an irregular pulsation of water through the extraction tube which indicates irregular water flow); (2) maximize tube penetration into the saturated zone; and (3) maximize the groundwater flow rate by optimizing the applied vacuum to the well's annular space.

Typical installation activities require connection of a power supply, piping and vacuum system leveling, connection to the extraction well(s), and connection of vapor and liquid-phase discharge connections to the final treatment process(es).

WASTE APPLICABILITY:

This technology is designed to remove VOCs from groundwater and soils.

STATUS:

The Xerox 2-PHASE™ EXTRACTION process was accepted into the SITE Demonstration Program in summer 1994. The demonstration began in August 1994 at a contaminated groundwater site at McClellan Air Force Base in Sacramento, California and was completed in February 1995. The demonstration was conducted in support of the McClellan Public-Private Partnership coordinated by Clean Sites, Inc. Reports of the demonstration are in preparation.

The Xerox 2-PHASE™ EXTRACTION process is a patented technology. Six patents were issued from 1991-1995 and several patents are pending. The 2-PHASE™ EXTRACTION process technology is available under license and is being used extensively in the United States, Canada, South America, Great Britain, and Europe.

DEMONSTRATION RESULTS:

Results from the demonstration are detailed below:

- The total contaminant (trichloroethene, tetrachloroethene, Freon 133™) mass removal during the 6-month demonstration was estimated at 1600 pounds, of which 99.7 percent was extracted from the vapor phase.
- The system simultaneously extracted 1.4 million gallons of groundwater and 24.4 million cubic feet of soil vapor.
- The radius of capture in the groundwater extended from 100 to 300 feet from the extraction well. The radius of influence in the vadose zone extended 200 feet from the extraction well.
- The estimated cost of using the 2-PHASE™ EXTRACTION process was $28 per pound compared to an estimated $1370 per pound for a conventional pump and treat system.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Paul dePercin
U.S. EPA
National Risk Management Research Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7797
Fax: 513-569-7105
E-Mail: dePercin.Paul@epamail.epa.gov

TECHNOLOGY DEVELOPER CONTACT:
Ron Hess
Xerox Corporation
800 Phillips Road
Building 304-13S
Webster, NY 14580
716-422-3694
Fax: 716-422-9211
E-mail: ronald hess@wb.xerox
Web Site: www.xerox.com/ehs/remed.html

TECHNOLOGY USER CONTACT:
Phil Mook
SM-ALC/EMR
5050 Dudley Boulevard, Suite 3
McClellan AFB, CA 95652-1389
916-643-5443
Fax: 916-643-0827
E-mail: mook.phil@sma1.mcclellan.af.mil

ZENON ENVIRONMENTAL INC.
(Cross-Flow Pervaporation System)

TECHNOLOGY DESCRIPTION:

The ZENON Environmental Inc. (ZENON), cross-flow pervaporation technology is a membrane-based process that removes volatile organic compounds (VOC) from aqueous matrices. The technology uses an organophilic membrane made of nonporous silicone rubber, which is permeable to organic compounds, and highly resistant to degradation.

In a typical field application, contaminated water is pumped from an equalization tank through a prefilter to remove debris and silt particles, and then into a heat exchanger that raises the water temperature to about 165°F (75°C). The heated water then flows into a pervaporation module containing the organophilic membranes. The composition of the membranes causes organics in solution to adsorb to them. A vacuum applied to the system causes the organics to diffuse through the membranes and move out of the pervaporation module. This material is then passed through a condenser generating a highly concentrated liquid called permeate. Treated water exits the pervaporation module and is discharged from the system. The permeate separates into aqueous and organic phases. Aqueous phase permeate is sent back to the pervaporation module for further treatment, while the organic phase permeate is discharged to a receiving vessel.

Because emissions are vented from the system downstream of the condenser, organics are kept in

Pilot-Scale Cross-Flow Pervaporation System

solution, thus minimizing air releases. The condensed organic materials represent only a small fraction of the initial wastewater volume and may be subsequently disposed of at significant cost savings. This process may also treat industrial waste streams and recover organics for later use.

WASTE APPLICABILITY:

Pervaporation can be applied to aqueous waste streams such as groundwater, lagoons, leachate, and rinse waters that are contaminated with VOCs such as solvents, degreasers, and gasoline. The technology is applicable to the types of aqueous wastes treated by carbon adsorption, air stripping, and steam stripping.

STATUS:

This technology was accepted into the SITE Emerging Technology Program (ETP) in January 1989. The Emerging Technology Report (EPA/540/F-93/503), which details results from the ETP evaluation, is available from EPA. Based on results from the ETP, ZENON was invited to demonstrate the technology in the Demonstration Program. A pilot-scale pervaporation system, built by ZENON for Environment Canada's Emergencies Engineering Division, was tested over a 2-year period (see photograph on previous page). During the second year, testing was carried out over several months at a petroleum hydrocarbon-contaminated site in Ontario, Canada.

A full-scale SITE demonstration took place in February 1995 at a former waste disposal area at Naval Air Station North Island in San Diego, California. The demonstration was conducted as a cooperative effort among EPA, ZENON, the Naval Environmental Leadership Program, Environment Canada, and the Ontario Ministry of Environment and Energy.

Organics were the primary groundwater contaminant at the site, and trichloroethene (TCE) was selected as the contaminant of concern for the demonstration. The Demonstration Bulletin (EPA/540/MR-95/511) and Demonstration Capsule (EPA/540/R-95/511a) are available from EPA.

DEMONSTRATION RESULTS:

Analysis of demonstration samples indicate that the ZENON pervaporation system was about 98 percent effective in removing TCE from groundwater. The system achieved this removal efficiency with TCE influent concentrations of up to 250 parts per million at a flow rate of 10 gallons per minute (gpm) or less. Treatment efficiency remained fairly consistent throughout the demonstration; however, the treatment efficiency decreased at various times due to mineral scaling problems.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Ronald Turner
U.S. EPA
National Risk Management Research Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7775
Fax: 513-569-7676

TECHNOLOGY DEVELOPER CONTACT:
Chris Lipski
ZENON Environmental Inc.
845 Harrington Court
Burlington, Ontario, Canada
L7N 3P3
905-639-6320
Fax: 905-639-1812

ZENON ENVIRONMENTAL INC.
(ZenoGem™ Process)

TECHNOLOGY DESCRIPTION:

ZENON Environmental Inc.'s, ZenoGem™ Process integrates biological treatment with membrane-based ultrafiltration (see figure below). This innovative system treats high strength wastes at long sludge retention time but short hydraulic residence time. As a result, the bioreactor's size is significantly reduced. Membrane filtration reduces the turbidity of the treated wastewater to less than 1 nephelometric turbidity unit.

In the ZenoGem™ Process, wastewater contaminated with organic compounds first enters the bioreactor, where contaminants are biologically degraded. Next, the process pump circulates the biomass through the ultrafiltration membrane system, or ultrafilter. The ultrafilter separates treated water from biological solids and soluble materials with higher molecular weights, including emulsified oil. The solids and soluble materials are then recycled to the bioreactor.The ZenoGem™ Process captures higher molecular weight materials that would otherwise pass through conventional clarifiers and filters. The ZenoGem™ Process pilot-scale system is mounted on a 48-foot trailer and consists of the following six major components:

- Polyethylene equalization/holding tank: reduces the normal flow concentration fluctuations in the system
- Polyethylene bioreactor tank: contains the bacterial culture that degrades organic contaminants
- Process and feed pumps: ensures proper flow and pressure for optimum system performance
- Ultrafiltration module: contains rugged, clog-free, tubular membranes that remove solids from treated water
- Clean-in-place tank: includes all the necessary valves, instrumentation, and controls to clean the membrane filters
- Control panel and computer: monitors

ZenoGem™ Process

system performance

The treatment capacity of the pilot-scale, trailer-mounted system is about 500 to 1,000 gallons of wastewater per day; however, a full-scale system can treat much larger quantities of wastewater. The trailer is also equipped with a laboratory that enables field personnel to conduct tests to evaluate system performance. The system is computer-controlled and equipped with alarms to notify the operator of mechanical and operational problems.

WASTE APPLICABILITY:

The ZenoGem™ Process is designed to remove biodegradable materials, including most organic contaminants, from wastewater to produce a high quality effluent. The process consistently nitrifies organics and can denitrify organics with the addition of an anoxic bioreactor. The process is limited to aqueous media and may be used to treat high strength leachates, contaminated groundwater, and soil washing effluent.

STATUS:

The ZenoGem™ Process was accepted into the SITE Demonstration Program in summer 1992. The ZenoGem™ Process was demonstrated at the Nascolite Superfund site in Millville, New Jersey from September through November 1994. Groundwater at this 17.5-acre site is contaminated with methyl methacrylate (MMA) and other volatile organic compounds from manufacturing polymethyl methacrylate plastic sheets, commonly known as Plexiglas. The Demonstration Bulletin (EPA/540/MR-95/503) and Technology Capsule (EPA/540/R-95/503a) are available from EPA. The Innovative Technology Evaluation Report will be available in 1997.

Since the development of the ZenoGem™ technology in 1987, ZENON has performed pilot tests for government and private clients on several different types of wastewater, including oily wastewater, metal finishing wastes, cleaning solutions containing detergents, alcohol-based cleaning solutions, landfill leachate, aqueous paint-stripping wastes, and deicing fluids. Information about the two demonstrations conducted in Canada and the United States is available from ZENON.

DEMONSTRATION RESULTS:

During the 3-month demonstration, sampling results showed that the system achieved average removal efficiencies of greater than 99.9 percent for MMA and 97.9 percent for chemical oxygen demand. MMA concentrations measured in the off-gas emission stream indicated insignificant volatilization. The ultrafiltration system effectively dewatered the process sludge, which yielded a smaller waste volume for off-site disposal. Sludge dewatering resulted in an approximate volume reduction of 60 percent and a solids increase from 1.6 to 3.6 percent. The process effluent was clear and odorless, and accepted for discharge by the local publicly owned treatment works. During the demonstration, the system was left unattended at night and on weekends, demonstrating that computer control is practical for extended operating periods.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Daniel Sullivan
U.S. EPA
National Risk Management Research Laboratory
2890 Woodbridge Avenue
Edison, NJ 08837-3679
908-321-6677
Fax: 908-321-6640

TECHNOLOGY DEVELOPER CONTACT:
F.A. (Tony) Tonelli or Philip Canning
ZENON Environmental Inc.
845 Harrington Court
Burlington, Ontario, Canada
L7N 3P3
905-639-6320
Fax: 905-639-1812